

Institution: University of the West of England, Bristol

Unit of assessment: 12 Engineering

Section 1. Unit context and structure, research and impact strategy

Department Context

The **Department of Engineering Design & Mathematics (EDM)** focusses on fundamental and applied research in three key areas; robotics; engineering simulation and modelling; and machine vision. Fostering links through industry partnerships enables staff to extend the impact of their work into domains such as agri-tech, connected and autonomous vehicles, aerospace engineering and healthcare. Much of the Department's work is carried out in multi-disciplinary teams and draws on other disciplines from across the Faculty and University, including computer science, psychology, microbiology and neuroscience.

Department Structure and Synergies

The Department comprises seven research teams with distinctive expertise and facilities. These are organised in:

1. Four University-recognised Centres with established international records of excellence and achievement.
2. Three Faculty-recognised Groups, smaller in scale and output, but typically growing towards Centre status.

Each Centre and Group is led by a Professor who also serves as its representative on the Faculty's Research and Knowledge Exchange Committee which ensures that all the teams have a forum to confer and collaborate on UWE research strategy implementation and investment. In addition, the Centres are physically co-located (see section 3), lending itself to cross-fertilisation of ideas and collaboration with stakeholders along the innovation pipeline.

The four Research Centres are:

1. The **Bristol Robotics Laboratory (BRL)**, co-led by **Melhuish and Giuliani**. Located on UWE's Frenchay Campus, BRL is a long-standing collaboration with the University of Bristol harnessing the collective strengths of both Universities, bringing together expertise from industrial collaborators and both academic communities, positioning it as one of the global leaders in advanced robotics. BRL spearheads a wide range of fundamental research areas, including human-robot interaction, haptics, teleoperation, evolutionary robotics, neural architectures, artificial intelligence and ethics, underpinning applied research in surgical robotics and medical devices, assistive robotics, nuclear decommissioning, AUVs (drones), UAVs (robot submarines), CAVs (self-driving cars) and swarm robotics. In addition, it leads in developing methodologies for benchmarking and testing, validation and verification of autonomous systems. Applied research in BRL emerges from close collaboration with industry, driven by solving industrial challenges. This has also led to the incubation of new businesses and support for local SMEs to leverage the opportunities offered by robotics and automation.
2. The **Bristol BioEnergy Centre (BBiC)**, led by **Ieropoulos** emerged from a research group within BRL to become a fully-recognised Research Centre in 2014. The Centre specialises in waste and wastewater utilisation, as a source of bioenergy for practical applications – through bio-electrochemical systems – with a particular focus on bioengineering, ultra-low-power electronics, AI and smart energy harvesting for autonomous robots. BBiC demonstrated the world's first eating, drinking (and waste excreting) family of autonomous robots (EcoBots I, II and III and Row-Bot) at lab-bench scale and also Pee Power® (UWE's own trademark), the world's first self-lit toilet powered by human excreta. Almost two decades of work has taken this from table-top proof-of-concept to a licensable technology demonstrated in real-world environments. BBiC researchers develop and apply Microbial

Fuel Cell (MFC) technology to convert organic waste into electricity and potable waste by utilising the natural biodegradation ability of live electroactive microorganisms that generate electricity from waste directly, at ambient temperature and pressure, and without any other energy input. With sustainability and responsible innovation at the core of its activities, the Centre looks into biodegradable smart materials for decomposing MFCs and biodegrading robots, and advances the MFC technology for commercialisation, particularly in developing countries.

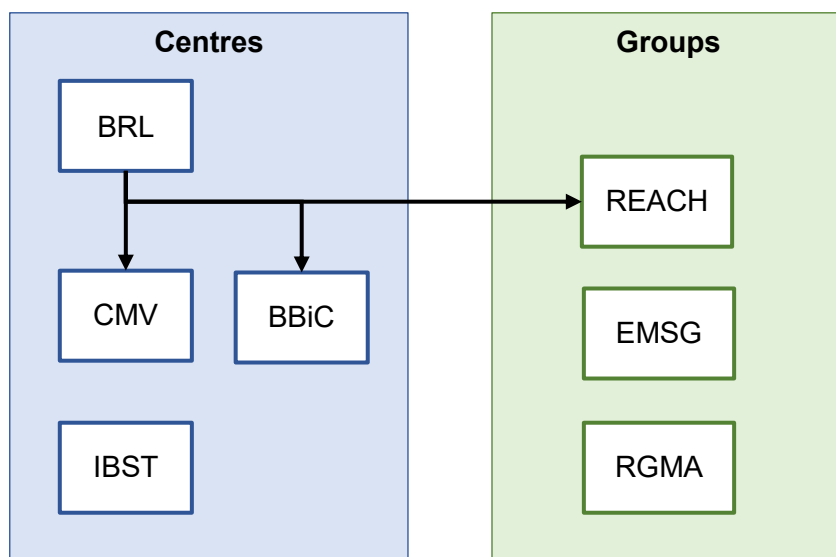
3. The **Centre for Machine Vision (CMV)**, led by **M Smith** became a University-recognised centre of excellence in 2006. Since 2013 it has been co-located and closely allied with the BRL in order to exploit synergies between research in machine vision and robotics. CMV researchers solve real-world computer vision problems, with a particular expertise in three-dimensional reconstruction and surface inspection. CMV is recognised as one of only three UK centres of excellence in the use of photometric stereo, a technique that uses multiple points of illumination to elucidate surface texture, 3D shape, depth and hidden features in a variety of different application domains across industry, medicine and defence. CMV is increasingly applying these techniques, coupled with 'deep learning' neural networks, to problems in agriculture, the food industry, monitoring of livestock health, grassland weeds, and similar complex sensing issues. It also applies the technology to other areas such as medical diagnosis, surveillance and manufacturing, typically in collaboration with industry.
4. The **Institute of Bio-sensing Technology (IBST)**, led by **Kiely**, has been a University Institute and beacon of cross-faculty, multi-disciplinary research since 2008, comprising researchers from the Faculties of Environment and Technology and Health and Applied Sciences. Within state-of-the-art laboratories, IBST researchers design complex biological tests, incorporating these into prototype devices using microfluidics and bespoke electronics. IBST researchers work closely with industry, particularly the growing sectors of healthcare, agri-food, environmental monitoring and security, to develop and deploy novel bio-sensing technology. Technologies currently being developed include bioluminescent reporter bacteria, impedance spectroscopy, microbial detection and biocontrol, paramagnetic particle-based detection systems, screen-printed biosensors, signal processing, and vapour sensing. IBST occupies a purpose-built suite of health technology laboratories, co-located with CMV and BBiC to explore areas where synergies can be exploited.

Groups in the Department represent emerging and growing areas of research:

1. The **Engineering Modelling and Simulation Group (EMSG)**, led by **Yao** was formed in 2013 to bring together control engineers, aerospace engineers and mathematicians with research interests in control systems, computational fluid dynamics, materials science, data analysis, mathematical modelling and simulation of complex systems. It aims to deliver high quality multidisciplinary research, postgraduate training, and consultancy services including finite element analysis, electrical control and operations, and process modelling and simulation. The Group is organised in four main themes: thermofluids and clean energy, digital engineering, smart materials, and intelligent systems and control.
2. The **Research Group into Mathematics and its Applications (RGMA)**, led by **Zverovich**, was formed in 2015 and focuses on inter-related research themes in applied mathematics and operational research to deliver high-quality research with impact through collaborations. Its main focus is the application of mathematical modelling and techniques to prediction and optimisation in areas such as transport, disease, decision support, logistics and scheduling, defence, sensing, metrology, and sustainable power generation. The Group works with researchers across a range of disciplines within and without the University in application areas such as health services, architecture and humanitarian logistics.
3. The **Robotics Engineering and Computing for Healthcare (REACH)** group, led by **Caleb-Solly** (whose work is submitted to UoA 11) but including **Etoundi**, **Jafari** and **Western**, was formed in 2016, emerging as a specialist discipline area within the Faculty. REACH takes a person-centered approach to the application of robotic technology in providing social and physical assistance for people with a range of disabilities to enable independent living. It has

strong industry and health links, including a partnership with the North Bristol NHS Trust launched in January 2020 to collaborate on the development of robotics and other healthcare technology to improve patient health and hospital experience. REACH runs the Assisted Living Lab, a certified European Robotics League Test Bed used for benchmarking assistive robots.

Figure 1: Overview of the relationship between the Department's Research Centres and Groups



Research objectives 2014-2020

The consistent and overarching strategy has been to undertake *research with impact* in partnership with industry and end-users, consolidate our staff base, and integrate research with teaching. This flowed from the emphasis on 'Research with Impact' within UWE's 2020 Strategy, adopted across the University in 2012-13.

The focus on research with impact was already prominent in the unit's REF 2014 submission, supported by an aim to strengthen partnerships, particularly with industry. In particular, objectives were to:

1. perform **research with impact** in selected areas of research that meet the needs of a sustainable economy and society;
2. further **strengthen interaction with industry** and form partnerships with end-users, recognising that knowledge exchange motivates research, leading to new collaborative projects and the commercialisation of research;
3. **consolidate** the Department's expanded **staff base** and ensure that the synergies between the talents of more recently appointed staff, alongside more established staff, are recognised, supported and developed thereby enabling new collaborations and avenues of scientific advance to evolve; and
4. more strongly **integrate research with teaching** to inspire and inform students as STEM subject popularity increases leading to new intakes at PhD level and, over time, extending the Department's network of external connections and prospects for collaboration.

In implementing this strategy, the Department has:

1. Ensured that staff have a shared vision of strategic expectations regarding undertaking research with impact by communicating and sharing information through a range of channels, including team meetings, away days, individual appraisals, newsletters and emails. In staff surveys, over 90% of staff indicated that they were aware of the strategy and understood their role in delivering it.

2. Incorporated these aims within the implementation plans of Research Centres and Groups, which regularly report on progress to the bimonthly Faculty Research Committee and via annual reports, including KPIs.
3. Developed and sought out opportunities to strengthen interactions with industry (see below).
4. Consolidated the staff base and integrated research with teaching alongside a steady increase in the number of postgraduate doctoral students (see Section 2).

Future research objectives

The UWE 2020 'Research with Impact' Strategy has been superseded by 'Strategy 2030' (see Institutional Statement) in which the focus on research with impact continues, but is further targeted on a set of priority areas. These 'Research Beacons' have been chosen with reference to existing research strengths and in relation to societal needs and global challenges over the next decade: digital futures; health and wellbeing; creative industries and technologies; sustainability and climate change resilience.

The strategic goal for the Department for the next five years is to conduct high-quality research with impact and focus investment towards those areas that directly contribute to the Research Beacons, developing collaborative and interdisciplinary research with academic and industry partners while increasing research capacity, including the number of doctoral students, researching in these themes.

Table 1 maps our existing research areas onto the Research Beacons, showing there is already a strong fit which will be reinforced through supporting growth in areas such as:

1. Digital engineering, through the creation of a new cross-departmental Institute
2. Healthcare technology, expanding and integrating currently dispersed research

The priority areas will inform recruitment strategy, as well as the allocation of resources to nurture emerging researchers.

Table 1: Mapping of Department research against UWE Research Beacon themes

Centres /Groups	Digital Futures	Health & Wellbeing	Creative Industries and Technology	Sustainability and climate change resilience
BRL	Connected and Autonomous vehicles, Teleoperation in hazardous environments	Teleoperation	Simulation environment and Virtual Reality	
BBiC	Living architecture			MFC technology for renewable energy
CMV	Face recognition	Machine-aided diagnosis		Agri-tech
IBST		Bio-sensing in health		Bio-sensing in agri-tech
EMSG			Digital engineering	Smart materials, clean energy
REACH		Assistive robotics, Smart-home sensing, Intelligent prosthetics	Telepresence robotics for access to the Arts	
RGMA	Disaster modelling	Pharmakinetics		Weather modelling

Enabling and facilitating impact

The strategic focus on research with impact has driven a) the type of research undertaken, b) staff recruitment strategy with a focus on applied research skills and experience of real-world practice, c) the collaborations formed to enable a strong culture of networking with end-users, and d) the types of funding sought in order to facilitate impact.

To enable and facilitate impact, the Department has:

1. Selectively supported impact-oriented research via:
 - a. Internal funding of dedicated research time, focusing on individuals with clear and realistic plans for bidding and on potentially impactful research collaborations.
 - b. Targeted resource allocation to Research Centres and Groups to reinforce their alignment with the strategic priorities.
 - c. Internal competitions for impact-focussed research funding such as the Vice-Chancellor's Early Career Researcher Scheme (VCECR), and the Vice-Chancellor's Interdisciplinary fund.
 - d. Activities that bring researchers together from different disciplines, with opportunities to bid for dedicated funding for proof-of-concept projects aimed at promoting routes to impact.

2. Accessed support from the University's central business development and technology transfer service, *Research, Business and Innovation* (RBI) to assist researchers in identifying collaborators and appropriate funding calls, including Knowledge Transfer Partnerships, and advise on commercial aspects such as IP and licensing issues. For example, the Department has been actively involved in RBI networking groups within the University aligned to national priority areas such as healthy ageing, clean growth, and sustainability. These have enabled researchers to form interdisciplinary collaborations with the collective potential to tackle complex problems. As a result, two spin-out companies, Nidor Dx and BreathDx, have been formed to exploit bio-sensing technology to develop a volatile signature analysis system to diagnose and monitor a range of medical conditions, involving IBST staff in collaboration with staff in Health and Applied Sciences.

3. Promoting industrial partnerships through a 50:50 PhD scheme where half the direct costs of the studentship comes from the Faculty, and the other half from an industrial partner. Currently there are five such studentships running in the Department.

4. Promoting collaboration and innovation through several European Regional Development Fund (ERDF) funded projects:
 - a. The *Robotics Innovation Facility* (RIFBristol) at BRL, established as part of an EC FP7 project to offer funded consultancy and short-duration R&D projects for SMEs. RIFBristol has continued in the form of the SABRE Programme, a million-pound project, co-funded by the ERDF, which offers bespoke engineering support to industry looking to explore the possible impacts of robotics and automation in their organisation. Over the REF period, 21 workshops were run, 471 businesses supported (including 414 SMEs), 79 new jobs created and £983k public funding won for 8 SME research collaborations.
 - b. IBST provides a membership service supporting a business network that brings together companies and research institutions interested in bio-sensing technology. IBST staff run the ERDF-funded *Innovation 4 Growth* programmes (£4.1M) which offers SMEs in South West England grants of between £10,000 and £75,000 to fund up to 35% of the total cost of research and development projects,
 - c. Emerging from IBST, the *Health Tech Hub* jointly runs the *Health Technology Accelerator Programme* (HTAP), funded by the ERDF to support SMEs in the West of England region in developing new products or services for the health and life sciences sector. Jointly run with the *West of England Academic Health Science Network*, the scheme offers free business coaching and mentoring for businesses that have an innovative product or service that can benefit the health and social care sectors.

5. The Department has supported the inception and growth of new companies by staff and students, and by innovators from outside the University, initiating new opportunities for collaboration, aligned to research strengths. For example:
 - a. The BRL *Incubator* and the UWE *Launch Space* have both supported technology start-ups with input from researchers, such as *Open Bionics* (3D-printed low-cost prosthetic arms for children), *Reach Robotics* (internationally acclaimed 'Mekamon' gaming robots), and *Altered Carbon* (graphene sensors for real-time low-cost gas detection).
 - b. The *University Enterprise Zone (UEZ)* in the adjoining *Future Space* facility, provides offices, workshops and lab space for science and tech-based businesses that have outgrown the incubator facility. It is estimated that Future Space will boost the regional economy by over £85M and create more than 450 jobs over the next 10 years.

How selected case studies relate to our approach to achieving impact

Impact, as illustrated by the submitted case studies, has its origin in research carried out over a 15-year period, reflecting a long-standing approach to supporting researchers to develop applications-focused research and build relationships with industry. For example, the MFC technology described in 'Pee Power – generating electricity from waste to improve safety and sanitation' was initially developed in the context of self-sustaining robots created by BRL. The technology was developed from generating electricity using waste materials into a new application in enhanced safety and illumination for users of night-time toilets, a major concern of the Bill and Melinda Gates Foundation. In collaboration with the Foundation, the technology has moved from the lab into the field and is now licensed to commercial developers.

The 'More sustainable and ethical agriculture through intelligent 3D machine vision' case study describes how researchers have developed the key technology of photometric stereo, enabling the reconstruction of 3D images from low-cost 2D cameras and applied it to challenges in agri-tech. Investment in CMV included funding small development projects and recruitment of key staff, along with technology transfer support from RBI and has led to impact in several agri-tech areas including automated crop data capture on a harvester, real-time livestock condition monitoring and detection and eradication of weeds in pasture.

Research underpinning the 'Informing responses to ethical challenges arising from the use of robots and AI' case study was supported over many years through a dedicated Chair in Robot Ethics, and through cross-Departmental support of interdisciplinary research. This led to EPSRC funding for work in *Robot Ethics*, including research on the ethical use and governance of autonomous systems, standards and regulation, and on how autonomous systems can themselves be ethical, i.e. be imbued with ethical values.

The 'Connected Autonomous Vehicles' case study describes how research into crucial issues raised by the introduction of autonomous vehicles to our roads and pedestrian areas has impacted on policy and practice. In collaboration with multi-sectorial partners, this work was supported by investment in interdisciplinary research, technology transfer support and partnerships with the West of England Combined Authority (WECA) and with industry. Seven multi-partner projects with *Innovate UK* with funding of about £17.5M since 2015 resulted in the formation of the VENTURER Alliance, which aims to investigate the socio-economic impacts of CAV, such as human acceptance, and insurance/legal issues. This has already given rise to further consultancy and other impact-generating projects such as the £5.5M multi-sector FLOURISH project.

Alongside research with clear routes to impact, the Department also undertakes fundamental research with longer-term prospects for application, for example:

1. An EMSG project which presents a universally feasible U-neural network (U-NN) structure to facilitate the designing control of all dynamic systems modelled with linear/nonlinear polynomial/state space equations.
2. An EMSG Detached Eddy Simulation study of the three-dimensional trailing-edge (TE) cutback turbine blade model with five rows of staggered circular pin-fin arrays inside the cooling passage, in order to evaluate the cooling performance in relation to coolant ejection

slot angle. The findings seek to improve existing TE cutback turbine blade design to achieve optimum film-cooling performance.

3. BRL researchers have conducted trials across Europe which confirm that the 'emotions' displayed by the Pepper robot can be appropriately interpreted, and that these 'emotions' change the extent to which robots are viewed as social agents, with implications for robot ethical standards and future robot design.

Supporting interdisciplinary research

The Department is by nature interdisciplinary, exemplified by its major Research Centres, BRL and IBST. This stems from the focus on addressing real-world problems which require expertise from a range of disciplines. Explicit funding to support and encourage interdisciplinary research has been provided throughout this REF period, building on the success of the EPSRC Bridging the Gaps project "Health, Environment and Technology Research: HEAT@UWE" which provided a model for initiating interdisciplinary research between colleagues across UWE. This has continued in this REF period and includes speed-research networking events where researchers have the opportunity to share their ideas with colleagues from other disciplines such as computer science, built environment, applied sciences, business and health, leading to a growing number of collaborations. For example, **Laister** (RGMA) collaborates with colleagues in Applied Sciences on modelling plant pathogens, resulting in a successful BBSRC-funded project to study 'Effector gene persistence in bacterial plant pathogens'. **Ieropoulos** (BBiC) is collaborating with colleagues from the Unconventional Computing Laboratory on embedding microbial fuel cells in buildings, funded by the European Commission (LIAR project).

The University has invested in a series of interdisciplinary pump-priming projects, for example combining expertise on advanced materials and manufacture with biochemistry to investigate a novel bone graft technique (**Bolouri**, BBiC), and on machine vision coupled with bacteriology to seek a faster way of detecting dangerous biofilms in food preparation environments (**Hansen**, CMV).

Open Research

The University explicitly encourages "researchers to be as open as possible, as early as possible, and to explore options for open access publication of research findings and open sharing of data" (see Institutional Statement). In support of this, there has been an open access repository for research outputs since 2010, and an open access data archive where data from research projects is curated and shared. All research students are obliged to use the data archive to make their research data available. Staff can access funding to cover open access costs for UKRI funded projects, and there are further funds to support costs for open access publications resulting from non-UKRI funded research. All PhD theses are digitised and downloadable from the UWE repository, except occasionally where commercial interests may lead to a delay in publication.

Culture of Research Integrity

The Department has taken a particular lead within the University in promoting excellent research that observes the highest standards of integrity. Both the current and former Chairs of the Faculty Research Ethics Committee (FREC), **Clark** and **Studley**, are active research leaders within the Department, and have worked across the University to promote excellence in ethics, and more broadly across research integrity and governance.

In doing so, the Department cooperates closely with the University's central research governance team to support researchers to embrace and meet the requirements of the *Concordat to Support Research Integrity* (Universities UK, 2018) which shapes the University's *Code of Good Research Conduct* (updated 2018) and its *Research Misconduct Procedure* (updated 2018). Researchers are required to create and maintain a *Research Governance Record* (RGR) for all projects that aims to ensure that all research undergoes a check to identify areas of potential risk that can be assessed and mitigated by appropriate professional support, including, for example, collecting, storing and managing sensitive and confidential research data. The current FREC chair (**Studley**) has been appointed to a Faculty role of Associate Professor in Technology Ethics to reflect his expertise and the Department's commitment to promoting best practice in research integrity.

Section 2. People

Staffing strategy and staff development

During the assessment period, the Department has grown, while at the same time seeing a turnover in senior staff who have retired or moved to new posts. The key staffing strategies have been (a) the recruitment and development of research-active staff, and (b) succession planning in research leadership.

Recruitment

The growth and turnover of the Department has allowed it to increase its staff base to achieve greater depth in core areas of research expertise. Since 2014, the Department’s aim has been to recruit new staff with a strong research profile, an ambition to continue their research in areas aligned to the Department’s research priorities and have industry experience and networks of external contacts to foster collaboration.

To this end, over 25 new appointments have been made across the seven Centres and Groups since 2014 and the proportion of active researchers has increased substantially over the period as a result of both recruitment and development strategies. In 2014, 19 staff in the Department were submitted to the REF (21% of all staff), across three different UoAs. For REF 2021, just over 40% of staff (50 FTE) are considered to have significant responsibility for research (some being submitted to other units, such as medical statisticians to UoA 3). This represents a step change in the proportion of staff who are active researchers in the Department. New recruits have mostly been early career academics, many arriving from postdoctoral positions.

Mindful of succession planning for research leadership, the Department has recruited senior staff to leadership roles (**Yang** and **Giuliani** came in as Professors) as well as cultivating potential future research leaders via ‘new blood’ lectureships (**Soe, Western, Yue, Zhang**). UWE’s ‘new blood’ scheme ring-fences 50% of the holder’s time for research over their first 3 years, by which time it is expected that they will be generating significant external research income.

The Department also initiated a Graduate Tutor Scheme to provide a structured opportunity for individuals to undertake a PhD with a lectureship to follow. The scheme provides academic training and some teaching alongside a 5-year part-time PhD to smooth the transition into a lectureship role. This has provided a pipeline of new academics well-aligned to existing research strengths. The first three graduates completed their PhDs with two having joined the Department as Lecturers (the third has taken a job in industry).

Figure 2: Staff profile by contract type 2013-2019

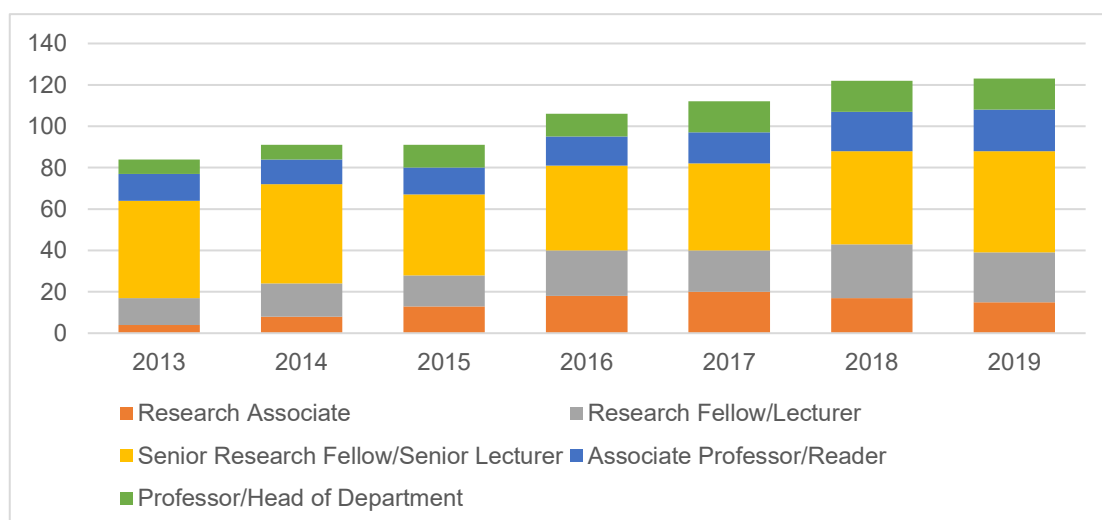


Table 2: Fixed term and permanent research-only staff by FTE and Headcount

HR data as of 31/07/2020	Fixed Term		Permanent	
	FTE	Headcount	FTE	Headcount
Research Associate	7.8	8	1.0	1
Research Fellow	8.8	10	0.6	1
Senior Research Fellow	0.5	1	4.9	5
Total	17.1	19	6.5	7

Staff Development Strategy

The Department has supported all staff, irrespective of career stage, to pursue research and/or scholarly activity. All academic staff have a contractual allocation of 25 days a year to undertake scholarly activity with support and guidance being provided for those who wish to use this for research. Others may use it to develop their teaching, professional society activities, or to engage with industry, for example through consultancy.

All staff have an annual Performance Development Review (PDR) with a senior member of staff in which they reflect on their research aspirations, with an expectation that they will have objectives relating to research or knowledge exchange. Staff can apply for additional time to undertake research, to progress dissemination and impact from their work and to pursue initiatives for new projects and external funding. Priority is given to staff whose plans are aligned to University research priorities with ambitious but realistic plans for what they will deliver.

Development time and resources are also provided for staff at particular career stages:

Support for early career researchers

The Department is committed in its support for early career researchers, using the various mechanisms elucidated in the Institutional Statement. All new appointments, including part time staff, are given one day per week of research time, in addition to their scholarly time, for the first two years of their appointment to establish and progress their research trajectory. Additional time is provided for staff appointed through the 'new blood' scheme, mentioned above, appointees being highly promising individuals in priority research areas who bring experience and commitment in learning, teaching and research and the synergies between them. The Department has been awarded four such posts over the REF period (**Soe, Western, Yue, Zhang**).

Newly-appointed academic staff are provided with advice and mentoring to help them grow into their role and advance their research, including support from a member of the senior management team with responsibility for research (**Studley**), who signposts them to the appropriate research group. Senior members of research groups provide mentoring to staff and RBI provides individual support to new starters to enable them to identify appropriate bidding opportunities and develop bids. For staff who identify as female, the University has a Women in Research Mentoring Scheme that promotes equality and facilitates professional development for women researchers across all faculties. Five members of staff in the Department have benefited from having a dedicated mentor through this scheme (including **You, Toomer** in this submission), some of whom have moved from fixed term contract to permanent roles and/or been promoted (e.g. **Toomer**). Staff in the Department have acted as mentors in the scheme (e.g. **Clark**), which is now also chaired by the Faculty Associate Dean (Research).

At Faculty level, an annual starter's away day introduces staff to Faculty and University research strategy and to the various services and systems they will need to interact with in order to pursue research. Early-career academic staff are required to enrol in the Academic Development Programme, accredited by the Higher Education Academy, which is designed to build an understanding of the structures and mechanisms within which staff operate as researchers, managers and teachers. The Department also encourages and supports research-grade staff to

attend in order to develop them as future academics. This has been instrumental in assisting five staff to progress from postdoctoral researchers on fixed-term contracts to permanent roles as Lecturers, Senior Lecturers and Associate Professors via competitive appointment processes (**Farooq, Hansen, Jafari, Atkinson, Zhang**).

Researcher training is available centrally on topics such as bid writing, research methods, research ethics, data management, and doctoral supervision. New staff are encouraged or required to undertake training as appropriate to their needs through the probation process and annual PDR. The University has invested in an annual competition for early career researchers (the VC ECR awards) for the last 12 years. Staff can bid for up to £15k to undertake novel research aligned to University priorities. This enables early career staff to develop new research directions, produce research outputs, and develop collaborations, as well as positioning them to bid for external funds. As a result of active encouragement and support, 21 of the 50 VCECR awards across the Faculty during the current REF period were to staff in the Department. **Ieropoulos**, an early recipient of a VCECR award has since progressed to Professor and now a Research Centre Director.

Support for mid-career researchers and future leaders

Mid-career staff are supported with:

1. Opportunities to bid to for internally funded time to undertake research leading to publications, write large scale bids for external funding or develop interdisciplinary and collaborative research projects.
2. Support from staff in RBI in matchmaking with potential business partners.
3. Team leadership-oriented training, such as recruitment and interviewing and personal development review training
4. Mentoring via their Research Centre/Group, or through the Women in Research Mentoring Scheme (where appropriate).
5. Access via competitive application to 'Accelerator' programmes designed to support mid-career staff to bid successfully for external funding. Three Departmental staff were selected for the 2019 cohort (including **Lemaignan** and **Toomer**), and four for the 2020 cohort (**Soe, Western, Pearson, Bolouri**).

Much of the support available to early career researchers is also available as appropriate to those in mid-career in order to update their skills and refresh their knowledge of research policy and good practice.

Senior research leaders

Senior staff, typically Associate Professors and Professors, automatically receive an allowance of internally funded time to undertake research that will lead to significant outputs and/or new bid development. Those leading or co-leading a Research Centre or Group receive an additional allocation of time to manage their Centre/Group. In addition to development opportunities available to other researchers, senior staff are offered training in a range of areas, including project management, interviewing, performance development reviewing and managing stress. Professors have the opportunity to participate in 360 degree reviews, including the use of professional, independent coaches to explore their ambitions and strategies for personal and professional development.

Policy for research leave

Staff, including those on part time or fixed term contracts, are able to bid to the Department for up to 20% of their time annually to undertake research, as noted above. Typically, this time is taken throughout the year rather than in a concentrated block of research leave.

Evidence of procedures to stimulate and facilitate exchanges between academe and industry

In addition to the examples of interaction with industry described in section 1, a key element of the Department's staff development strategy is to promote academic enrichment through externally funded fellowships and visiting scholars. Visitors and wider virtual academic networks promote sustainable collaboration and encourage research 'without borders'. Notable examples during the period include Royal Academy of Engineering Industrial Professorships:

- Dr Raj Nangia, Visiting Professor in Aerospace Vehicle Performance and Aerodynamics (**Toomer**, EMSG)
- Dr Paul Taylor, Visiting Professor in Rotocraft Stability and Control (**Toomer**, EMSG)
- Dr Christopher Harrison Visiting Professor in Design/Analysis and Optimisation of Composite Structures (**Damghani**, EMSG)

Other Visiting Professors/Scholars include:

- Professor Mark Calloway, University Hospitals Bristol (**Melhuish**, BRL)
- Dr J. Fang, Leverhulme Visiting Researcher (**Yao**, EMSG).
- Dr Ian Hales, Machine Learning Engineering, Boeing (**M. Smith**, CMV)
- Dr Lili Tao, Senior Machine Learning Engineer, Dyson (**M. Smith**, CMV)
- Professor Sanja Dogramadzi, Medical Robotics, Sheffield University (Caleb-Solly, REACH)

Recognition and reward for staff carrying out research and achieving impact

Success in delivering high quality research and delivering impact are recognized as key elements of the promotion criteria for Associate Professor and Professor. These are also criteria that drive Departmental resource allocations, including time and financial resources.

A number of reward mechanisms are open to staff, including:

- Professorial Merit Pay, an annual, self-elective scheme with the aim of recognising and retaining high-performing senior staff.
- An annual Exceptional Contribution Honorarium scheme, through which management teams can give recognition to individuals and/or groups who have made a significant contribution to the University, including research, for example, **Hansen** (CMV) in 2019;
- Researcher of the Year, an annual scheme through which staff can nominate an individual who has performed exceptionally, for example, **Laister** (RGMA) in 2018 for his multi-disciplinary work on applications of non-linear partial differential equations.

Postgraduate Research

Within the Department, there is a commitment to maintaining a vibrant and high-quality environment for research students. All research students have a Director of Studies (DoS) supported by a supervisory team. Each potential student is interviewed by a panel, chaired by the Department's member of the Faculty Research Degrees Committee (**Clark**), along with the member of staff most likely to become the DoS and those most likely to form the rest of the supervisory team (including any external collaborator).

As detailed in the Institutional Statement, UWE has a University-wide Graduate School to provide a consistent and well-resourced support service, enable the sharing of good practice and support for cross-disciplinary research. Each newly enrolled student has a training needs assessment with the supervisory team and a series of research training workshops is provided to give both essential research and transferable skills. All PhD students take 60 credits of taught courses before completing their award, which can include topic-specific level M taught courses.

The Faculty runs an annual one-day conference at which PhD students present work in mixed sessions thereby encouraging cross-disciplinary discussions and the sharing of good practice, as well as aiding preparation for external events. Groups encourage their students to attend and/or give regular seminars, and to interact with visiting academics and project-based researchers. The Department expects that all students will write and present a paper(s) for an external event(s), ranging from a UK workshop to international conferences, closely mentored by the supervisory team, with further support via writing courses available in the Faculty and Graduate School.

As part of the Department's impact strategy, studentships are available where 50% of the direct cost is contributed by an external partner, initiated by a lead academic as part of their networking activities (see Section 1). Current partners reflect a wide scale of commercial organisations, including large companies such as GKN, SMEs such as B-Hive Innovations Ltd and Meeg Solutions and charities such as Above and Beyond, which supports patient care in Bristol hospitals.

Student progress is formally monitored annually with reports from the student and supervisory team scrutinised by a Faculty Research Degrees Committee enabling, for example, the identification of good practice and students requiring extra support. Supervisory teams are expected to meet with the student regularly and maintain an agreed record of the outcomes. Students must produce a Progression Report before the end of the first 12 months (or equivalent for part-timers), which is examined by two members of staff not directly involved with the research/supervision. In March 2020 in response to the closure of the University campus due to COVID 19, the Department put in place extra social media and video conferencing groups with and without supervisory team member presence for all doctoral students.

The Department, through BRL, is a partner in the EPSRC Centre for Doctoral Training in Future Autonomous and Robotic Systems; FARSCOPE. The CDT takes a multi-disciplinary approach, aiming to give students the tools and contextual knowledge to tackle robotics challenges and create the next generation of innovators. In equal partnership with the University of Bristol (students gain a jointly-awarded PhD), FARSCOPE has supported around ten new studentships a year since 2014 with EPSRC grants worth £4.93m (2014-2022) and £4.85m (2019-2027). Completions are divided between the two Universities: 8 FARSCOPE students are included in the completions for this submission.

While the majority of PGRs are full-time, the Department also welcomes and supports part-time students, who comprise nearly a third of all PGRs. The majority of both part-time and full-time PGRs complete their PhDs within the relevant registration period.

The 2019 Postgraduate Research Experience Survey indicated that 77.5% of PGR students in the Faculty reported satisfaction in areas across their journey, from induction, to supervision, to having the necessary resources, access to professional development, through to preparation for the final submission and examination process.

Equality and diversity

The Department is fully engaged in ensuring equality and diversity in recruitment and support of staff. Active steps taken include:

- Ensuring all staff complete the UWE on-line equality and diversity training programme.
- Having a proactive engagement with Athena SWAN, with the successful renewal of a Departmental Athena SWAN Bronze award in 2019.
- Engaging with and sharing best practice on gender equality with others across UWE through the Athena SWAN Collaborative Group.
- Participating in the Women in Research Mentoring Scheme.
- Supporting the University's application to the Race Equality Charter Mark aimed at improving the representation, progression and success of black and minority ethnic staff and students within HE (within the Department there is strong representation of BAME staff at all levels, with around 35% of staff identifying as BAME).
- Supporting the University's engagement as a Stonewall Diversity Champion.
- Supporting staff to attend external training, including a specific BAME leadership programme (**Farooq**).
- Providing funds for PGR students to attend conferences or workshops, with childcare costs included as an allowable expense.

As part of the Department's successful Athena SWAN Bronze submissions (2014 and 2019), issues of gender and access to research support were investigated through a series of staff surveys and focus groups. The data showed that staff identifying as female did not perceive that they have lower access to research support than male colleagues.

Career pathways for part-time and fixed-term staff

Part-time staff have access to the same career pathways as full-time staff, with criteria for promotion taking account of the differential opportunities and experiences of staff working less than

full-time. Research grade staff are supported and encouraged to apply for promotion through the University's Research Grade Progression Group. Five Department staff have made this progression (**Ieropoulos, Lemaignan, Hansen, Pearson, Serruys**) of whom three have progressed through to Associate Professor/Professor during the REF period (**Ieropoulos, Lemaignan, Hansen**). Other fixed term research staff have moved into permanent lectureships through competitive application when vacancies arise (**Atkinson, Jafari, Western, Winfield J, Zhang**).

Equality and diversity issues in construction of REF submission

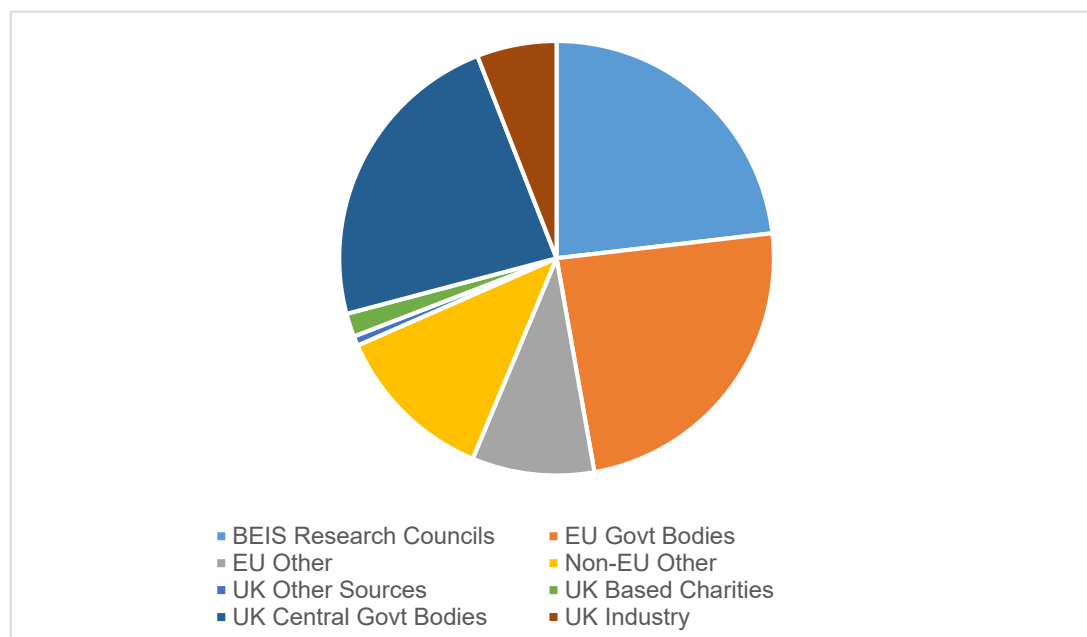
Within the unit, staff have been identified as having significant responsibility for research, being independent researchers, and outputs have been selected, in strict accordance with the University's Code of Practice. This includes selecting outputs on the basis of their quality as determined through a thorough peer review process with no expectation about the number of outputs any one individual contributes to the submission. Where it was necessary to choose between a small number of outputs with the same quality score to reach the required total, account was taken of the distribution of outputs between individuals and across the subject areas of the submission.

Section 3. Income, infrastructure and facilities

Research Income Strategy

As noted, the overarching strategy is to carry out research with impact in collaboration with external agencies through funds from a variety of sources. The Department's strategy continues to be for Research Centres and Groups to maintain a wide portfolio of external funding from different sources (see Figure 3). It is an explicit requirement that staff wishing to access internal funds for research develop a strategy to secure external funding to grow and sustain their work.

Figure 3: Proportion of research income by funder type 2013-2020



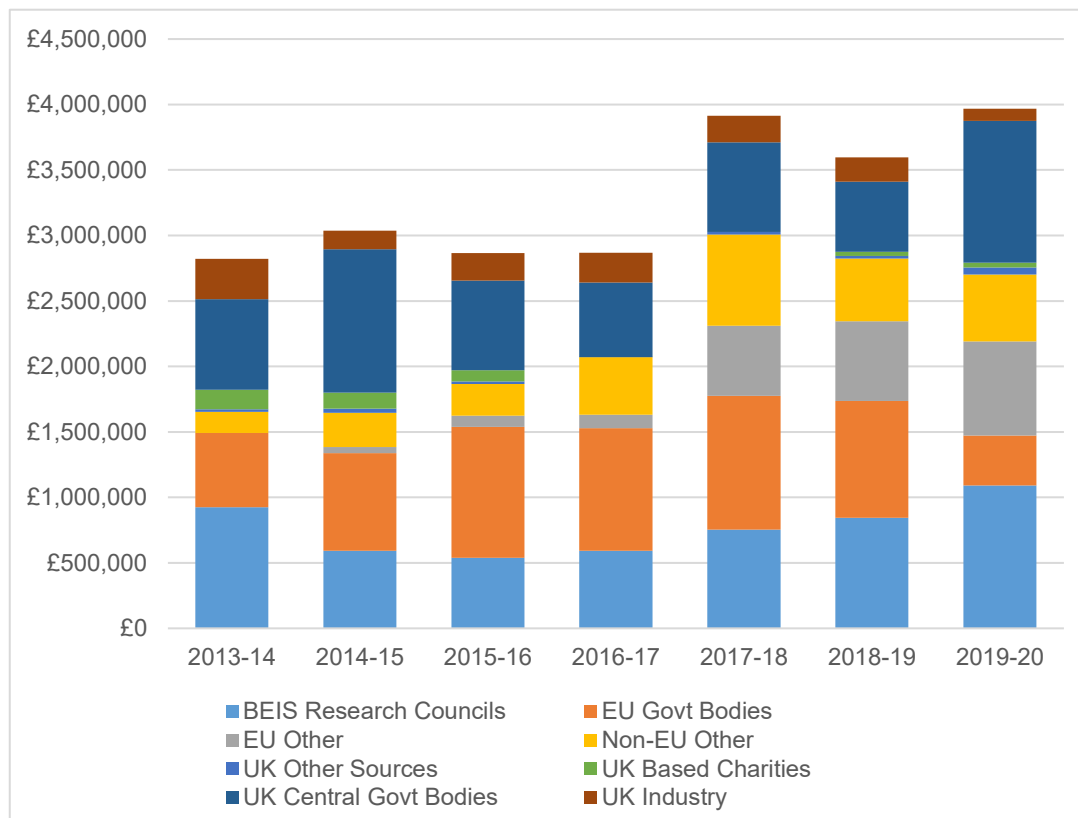
The bidding strategy has been to focus on:

- Collaborative bidding with major academic and industrial consortia, as exemplified by major initiatives such as 'Episodic Memory as multi-sensory reconstruction' (EC, with total funding of £64M), the National Centre for Nuclear Robotics (EPSRC), and Robopilot (Innovate UK).
- Collaborative bidding with industrial partners, including start-up SMEs, to move research nearer to market, for example CMV working with SME Agsenze Ltd on applying machine vision in agri-tech, resulting in a KTP (2018-2020) and a successful Innovate UK/BBSRC seed-funding bid (2019).
- Raising the international profile of our research, such as in robotics through the euRobotics

community, and in biosensing through founding and chairing the International Conference in Biosensing (now in its sixth year).

- Making an impact on funding policy, for example through influencing EPSRC funding calls in robot ethics and in making the case for robotics to be a UK national priority (see Section 4).

Figure 4: Research income 2013-2020



Support for bidding is provided by RBI, for example through weekly funding and networking opportunities updates, bid writing workshops, provision of an internal peer review process and maintenance of a research expertise directory for both internal and external collaborators. To support alignment with national priorities, staff are part of a Faculty Industrial Strategy Working Group, formed to promote engagement with emerging Government priorities. This has proven particularly effective for early career staff who have secured funding across a range of projects, from Grants4Growth, to KTPs, to Innovate UK projects.

Through these means, and through recruitment and staff development strategies, the Department has more than tripled research income, from £5.9M in the 2008-2014 period to £23M in the 2014-2020 period, an increase from £66k to £184k per FTE.

Alongside industry collaboration, many projects aim to create impact through social and community benefit. Examples include 'Urinetricity', a multi-phase BBiC project which has attracted £3M from the Bill and Melinda Gates Foundation to produce microbial fuel cell technology for rural off-grid areas in developing nations. Research into driverless cars (CAVs) has looked beyond the technological challenges to the wider impact on society, resulting in ongoing partnerships in the areas of transport, engineering, insurance and law. A series of successful Innovate UK bids in collaboration with Recycling Technologies has enabled researchers to test the impact of 'PLAXX' (a recycled fuel derived from plastic waste) on engine efficiency, wear, and longevity in marine engines and electricity generators on the grid.

Projects funded by ERDF and the Local Enterprise Partnership enable the Department to support SMEs in the region through research, consultancy and development work, helping to innovate and

provide a route to impact. For example, IBST secured £2m from ERDF for Innovation4Growth (I4G) to support SMEs in the region develop innovative products, technologies, processes and services, with grants between £10,000 and £75,000.

In other areas, such as simulation and modelling, staff have undertaken relevant research, without substantial external funding. Relatively low infrastructure costs have enabled staff in EMSG to deliver impactful results for industry through small grants. For example, a project to optimise turbofan-bearing coolant scoop geometry for Expleo (Assystem) has resulted in several candidate designs that can contribute towards more efficient and environmentally friendly aero-engines. The growth in staffing in the Department has resulted in a profile that is skewed towards relatively early career researchers, but despite this, bidding output and funding success continues to grow. However, recognising that the majority of larger grants are led by a small number of senior figures, some of whom are nearing retirement, the Department is working with mid-career staff via the University's mid-career accelerator scheme to target future research leaders and provide advice and guidance in constructing larger, collaborative and more ambitious bids and managing complex projects.

The growth of new research themes has been nurtured through internal investment to create a vibrant and diverse research culture. As informal groupings become sufficiently well developed with strong outputs and evidence of external esteem and impact, they can attain the status of a formal Group. Groups receive investment from the Faculty and engage in an annual process of goal setting, planning and reporting. Where Groups grow sufficiently in scale and impact, they are supported to make the case to become a recognised Centre, as was the case for BBiC in 2014. This evolutionary approach allows the Department to explore new routes to impact, and direct infrastructure funding according to the efforts and success of the staff involved. Groups, such as EMSG, RGMA and REACH are working towards Centre status and the Research Strategy 2030 Beacon areas will guide the future stages of this process.

Infrastructure and facilities

Specialist facilities support key areas of the research, particularly in robotics and related areas, and in healthcare technologies. A key strategy has been to consolidate research labs in the same physical area, adjacent to the business incubator and University Enterprise Zone (UEZ) in order to maximize synergies between them. BRL, CMV and BBiC are all co-located within this area, with a combined area of 4650m², including shared technical support and other facilities such as seminar and meeting rooms. Within BRL, the *Robotics Innovation Facility* (see above) has provided support to 620 clients, including 393 SMEs, to explore the use of automation and robotics.

Adjacent to the BRL and the UEZ, IBST established the *Health Tech Hub* (HTH) in 2018. A 900m² facility, this £5.6M investment focuses on user-led collaborative research to develop novel biosensors and home diagnostics, including devices and systems to support independent living. The infrastructure and equipment investment has enabled the HTH to secure 12 new grants (£4.4M value to UWE), support over 100 regional SMEs, enable the development of 15 new products, provide consultancy for several major companies and local councils, and collaborate in total with over 400 external companies.

In 2020, other parts of the Department moved into a new 8500 m² state-of-the-art Engineering building, close to the BRL, the HTH and the UEZ. The new Engineering Building is a £33M build, which includes facilities used for teaching and research such as engine test cells, wind tunnels and dedicated laboratories to accommodate a wide-range of engineering disciplines including composite manufacturing, machining and metrology. A specific design intention was that the building should facilitate working in partnership with regional industry.

In addition to buildings, significant improvements and investments across the Department since 2014 include:

- New BRL infrastructure including a fleet of autonomous vehicles, a full-vehicle immersive driving simulator for testing systems and driver interactions, new robots with manipulators such as Baxter, Pepper, and Tiago, a simulated nuclear decommissioning cell, wet labs for

bio-energy research. The Laboratory houses 17 specialist support staff and technicians. These investments, costing approximately £6M, have supported multi-disciplinary robotics research, with a community of over 40 academic staff.

- The HTH facilities include a surfaces/materials analysis suite, a sensor development and testing laboratory, a genomics laboratory, a cell culture facility, a prototyping facility, an electronics/instrumentation laboratory, a living lab (for near-to-real-world testing of devices/system) and a PPI (public and patient involvement) facility for user engagement. Key equipment includes a Raman spectrometer/microscope, Atomic force microscope, Biodot picolitre liquid dispenser, and DNA sequencers.
- Future Space, in the UEZ, has offices, workshops and lab-space for science and tech-based businesses, explicitly designed to encourage innovation and collaboration. It has rapidly filled, acting as an incubator, supporting collaboration, and enabling some of the impact described here. There are currently 46 companies based in Future Space, employing just over 300 people.

Section 4. Collaboration and contribution to the research base, economy and society

Collaboration

Partnering with other universities in the UK and internationally as well as with industry has enabled researchers to contribute their expertise within larger projects and therefore to enable their research to have wider reach and impact.

International collaboration

Many of the BRL projects extend beyond the two Bristol universities, in collaborations with numerous national and international external partners, with UWE providing an integrating role to enable the successful demonstration of robotic systems while drawing on many diverse skillsets and disciplines. The involvement of both Universities has led to a critical mass of over 40 researchers, enabling BRL to shape decision making (see below) and to engage with the largest and most successful European research institutions.

Examples of the consortia include EC-funded projects like SciRoc, Living Architecture (LiAr) and SmartSurg, which have involved collaborations with key players in Germany (Hochschule Bonn-Rhein-Sieg), Spain (Fundación Andaluza para el Desarrollo Aeroespacia, Universitat Politècnica de Catalunya, Centro de Investigaciones Biológicas (CIB), Consejo Superior de Investigaciones Científicas (CSIC), Portugal (Associacao do Instituto Superior Tecnico para a Investigacao e Desenvolvimento,), Italy (Politecnico di Milano, Sapienza - Università di Roma, University Degli Studi di Trento, Istituto Europeo Di Oncologia Srl), and Greece (Idiotiko Poliiatrio Orthopaidikis Chirourgikis Athlitikon) as well as international agencies such as the NATO Science and Technology Organisation and companies such as Liquifer Systems Group (Austria), Optinvent (France) and Hypertech Innovations Limited (Cyprus).

Regional consortia

The Department provides space for regional consortia bringing together key agencies, for example in the HTH, which is hosted and led by UWE and managed by a consortium comprising the West of England Academic Health Science Network, University of Bristol, and health tech companies Designability, Sirona and P3Medical. The HTH provides physical premises for interactions between academics, industry users and patients, to spread innovation, to improve healthcare and generate economic growth in the region.

Cross-faculty collaboration

Staff collaborate extensively with researchers across UWE on interdisciplinary research, for example with the Centre for Transport and Society on projects relating to autonomous vehicles, bringing together engineering expertise on the technical aspects of autonomous vehicles with social scientists considering issues relating to their societal acceptance. Within IBST, researchers collaborate extensively with colleagues in biological sciences on bio-sensing technology. BBiC researchers collaborate with the Unconventional Computing Lab on projects such as the EC-

funded 'Living Architecture' project which developed the concept of a selectively-programmable bioreactor as an integral component of human dwelling, extracting valuable resources from waste water and air, generating oxygen, and producing proteins and fibre, drawing on expertise in unconventional computing, microbial fuel cells, and construction engineering. RGMA researchers work with colleagues in the Centre for Architecture and the Built Environment in developing an algorithm for finding the optimal routes for search and rescue teams in a building in order to provide a decision-support system for emergency responses (funded by the QNRF Qatar Foundation).

Co-working facilities

Staff interact with key research users in a variety of ways, including the provision of co-working facilities such as the Assisted Living Lab (ALL) in BRL, developed in collaboration with a local charity, Anchor. The ALL has been used as a European Robotics League certified testbed for assistive robotics and technologies, and is currently part of the H2020 METRICS benchmarking project, hosting many groups of older adults and carers in usability tests. There is a dedicated facility for Patient and Public Involvement (PPI) as part of the development of the HTH, where health service users can input into the development and conception of new treatments and services.

Impact beyond academe

In addition to the impact case studies in this submission, there are many other examples of research making a contribution to the economy and society, for example:

- 'RoboTIPS: Developing Responsible Robots for the Digital Economy' is a five-year EPSRC funded project (£1.72M) in BRL with the overall aim of embedding responsible innovation in technology developers' practices and to create positive cases of RI in action.
- CMV collaborate with Aralia Systems Ltd (ASL), providers of intelligent surveillance solutions, to research a commercial security camera for the long-range detection of hidden weapons and suspicious objects using photometric stereo. Related work in 3D-imaging for remote face recognition with Cubic, providers of the Oyster Card, has led to a ticketless travel system demonstrator. A prototype device using both photometric stereo and multispectral imaging has been developed with ASL for non-contact palm identification under COVID-19 restrictions.
- Medical robotics research in REACH includes work to enable complex minimally invasive surgical operations by developing a novel robotic platform to assist the surgeon (EU-funded, £3.43M) and work with Paralympian athletes to develop quick-release mechanisms to enable prosthetic limbs to be interchanged more rapidly. An EPSRC first grant supported the initial work, which is having direct impact on users including Paralympic triathlete Andy Lewis.
- A collaboration between IBST and Mars-Wrigley focused on the development of a biosensing system for rapid detection of Cocoa Swollen Shoot Virus (a virus decimating cocoa plants across Africa), facilitated by two Innovate UK projects (totaling £1.4M), plus direct funding from the company. The work attracted grants supporting further collaboration with partners in Africa. The technology is patented and initial field trials took place in Ghana in 2020. There is potential for significant impact on the economy (the UK is a large chocolate producer), but also for substantial socio-economic impact in some African countries. Collaborations with the Conseil du Café-Cacao, Cocoa Research Institute of Ghana and Centre National de Recherche Agronomique de Côte d'Ivoire have developed from this research.
- NIHR-funded IBST research activity includes the development of point-of-care (POC) biosensors for diagnostics and health monitoring. Collaborators include: (i) respiratory consultants at the University Hospital of North Staffordshire to develop a smart saliva-based home diagnostic for prediction of exacerbations to allow interactive management of Chronic Obstructive Pulmonary Disease, (ii) urology consultants at North Bristol NHS Trust on a POC system for rapid diagnosis of Urinary Tract Infection in Primary Healthcare; (iii) consultants in anaesthesia, Royal United Hospitals, Bath for development of a POC system for monitoring patients undergoing Total Intravenous Anaesthesia.
- Funded by BBSRC, mathematicians in RGMA are working with bioscience partners in UWE, Oxford and Reading Universities in applying experimental evolution and dynamical systems theory to understanding the ways in which pathogenic bacteria develop resistance to the host

plant's defences. These resistance mechanisms pose a major threat to UK and global food security.

- REACH researchers collaborated with the charity Designability on the Innovate UK-funded project 'Care at Home using Intelligent Robotic Omni-functional Nodes', 2016-18, resulting in a prototype modular robotic system for use in care homes, and are collaborating with clinicians and therapists as part of the Robotics in Healthcare Demonstrator (2018-21) funded by the Lloyds Register Foundation via the University of York. REACH has also been working with ExtraCare Charitable trust, one of the largest providers of residential villages in the UK as part of a Knowledge Transfer Partnership.

Engagement with diverse communities

Engaging with diverse communities is a part of the wider engagement strategy. In particular, it is a priority to widen the pipeline to attract more female and BAME students into Engineering by influencing future engineers, and their influencers such as teachers and parents, by demonstrating the role of engineering in making positive impacts in the world. Consequently, there is an active programme of public engagement, in collaboration with UWE's cross-faculty Science Communication Unit, to undertake projects to communicate the value of engineering research to the public, including:

- National events, such as the 2018 Science Museum Robots exhibition featuring BRL's work on swarm robotics and the EPSRC-funded 'Heart Robot' project which explored public responses to robots.
- Regional events, such as the annual Bristol Festival of Nature, the UK's largest free festival of the natural world attracting some 35,000 visitors, which featured CMV's work on face recognition in pigs (2019).
- The world's first 'Robots in Smart Cities' event in Middleton Hall, Milton Keynes comprising a programme of public events, debates and interviews that showcased robotics to an estimated 500k people over the course of six days (2019).
- Regular 'Women in Engineering' days at UWE where research teams set projects for groups of female school students, reaching upwards of 500 female students over the period.
- A collaboration between BBiC and the Glastonbury Festival, initiated in 2015, which led to deploying a 'Pee Power' urinal on site in 2017 and again in 2019 to raise awareness of the power of engineering to change lives by demonstrating how urine can be used to provide illumination for users of night-time toilets, in refugee camps for example.

Responsiveness to national and international priorities and initiatives

A central aim has been to align research with national and international priorities. Staff are active within local, national and international networks to ensure they keep informed of priority research areas. For example, involvement with regional employers and the West of England Combined Authority enabled the Department to help shape the 2020 Digital Engineering Technology and Innovation initiative (DETI). Future strategy is to align with the University's Beacon research areas, themselves being chosen to respond to national and global challenges and UK Government investment priorities.

Wider influence and contributions to the research base

Strategic influence can be demonstrated both through individuals and through activities of Research Centres.

The BRL has had a notable impact on the UK's research landscape, being instrumental in the recognition of robotics as one of the UK Government's '8 Great Technologies', as noted by then Minister of State for Universities and Science, David Willetts in a letter of 23 July 2014 to BRL Director **Melhuish**; "*I remember very vividly my first visit to your robotics laboratory in Bristol. Your eloquence about robotics was one of the reasons why I was absolutely clear that it would be one of our eight great technologies that we are backing*".

A later visit to BRL by Greg Clark, then Business Secretary for Business, Energy & Industrial

Strategy, led to him noting that “*earlier this year the Government committed almost £1bn towards our AI Sector Deal, and the work Bristol Robotics Lab does to grow a new generation of robotics entrepreneurs is vital to this, across all four of our Grand Challenges*” (letter to **Melhuish**, 17 December 2018).

During the period, **Melhuish** hosted a number of UKTI/DIT sponsored trade missions, entertaining visiting Ambassadors and Ministers on 46 occasions from e.g. China, Japan, Malaysia, Macedonia, Lithuania, Luxemburg, Estonia, USA, Taiwan, Nigeria, Georgia, Finland, India; promoting the UK’s robotics capability, forging new collaborations and partnerships, and endorsing the UK as a destination for overseas foreign investment.

At individual level, **Winfield A** has had significant influence in the area of ethics, robotics and AI, as detailed in the impact case study. In addition, staff have contributed to UK Government Select Committee work, including written evidence submitted to the UK Parliamentary Select Committee on Science and Technology Inquiry on Robotics and Artificial Intelligence (**Winfield A**), oral evidence to the House of Lords Select Committee on Artificial Intelligence, and Autonomous Systems Network White Paper on agricultural robotics (**Smith M**).

Contributions to the research base

There are a range of indicators demonstrating the wider influence of staff, which include:

Peer Reviewing: EPSRC College members (16), NERC College members (2), BBSRC College members (2), Innovate UK grant assessors (2), EPSRC Panel membership (28), EU FP7 and Horizon 2020 project reviewing, advisors to Electronics, Sensors and Photonics KTN / Technology Strategy Board, Newton Fund, Medical Research Council, Government body reviewing in Netherlands, Canada, China, Switzerland, Finland.

Committees: Chair, Irish Composites Technical Steering Group (**Attwood**); Chair, Jury for 2014 EURO Awards for Best papers in European Journal of Operational Research (**Clark**); Member, Robotics and Autonomous Systems Special Interest Group (**Melhuish**); Member, EPSRC’s UK Robotics and Autonomous Systems Network (**Melhuish**); Co-founder, British Automation & Robot Association’s Academic Forum for Robotics (**Melhuish**); Member, European Commission’s Future Emerging Technologies Board (**Melhuish**); Chair, IEEE Standards Working Group on Transparency of Autonomous Systems (**Winfield A**), Member, EPSRC ICT Strategic Advisory Team (**Winfield A**), Member, British Standards Institute working Group AMT/010 Robotics (**Winfield A**), Member, Advisory Board, Institute for Ethical AI in Education (**Winfield A**), Member, Advisory Board, EPSRC/Industry-funded five-year Prosperity Partnership TB-PHASE (**Winfield A**), Member, Executive committee, IEEE Global Initiative for Ethical Considerations in Artificial Intelligence and Autonomous Systems (**Winfield A**), Member, UK Space Agency Space Exploration Advisory Committee (**Winfield A**), Expert advisor (Robot & AI ethics), Topol NHS HEE review, World Economic Forum Global Futures Council on The Future of Technology, Values and Policy (**Winfield A**); Member, Ethics Advisory Board for the EU FET Flagship Human Brain Project (**Winfield A, Pearson**); Chair, Chinese Automation Society in the UK (**Zhu**).

Journal editorship:

Editor in Chief: Biosensors (**Kiely**); International Journal of Modelling, Identification and Control (**Zhu**); International Journal of Computer Applications in Technology (**Zhu**); Sustainable Energy Technologies and Assessments (**Ieropoulos**).

Regional editor (Europe): International Journal of Intelligent Engineering Informatics (**Zhu**).

Associate Editor: Frontiers in Robotics (**Winfield A**); IEEE Transactions on Fuzzy Systems (**Yang**); IEEE Transactions on Automation Science and Engineering (**Yang**); IEEE Transactions on System, Man and Cybernetics: Systems (**Yang**); IEEE Transactions on Cognitive and Developmental Systems (**Yang**); International Journal of Fuzzy Systems (**Yang**); IEEE ACCESS (**Yang**); Neurocomputing (**Yang**); Frontiers in AI and Robotics (**Lemaignan**); Journal of Sustainable Energy Technologies and Assessments (**Ieropoulos**); Frontiers in Neurorobotics

(**Pearson**); SAE Aerospace Journal (**Zaidi**).

Guest editor: Special Issues on Machine Vision for Outdoor Environments (**Smith L**), 3D imaging in Industry Computers in Industry (**Smith L**); Special Issue Journal of Field Robotics (**Winfield A**), Frontiers in Robotics and AI, Special Issue on Machine Ethics (**Winfield A**), Proceedings of the IEEE (**Winfield A**); Human robot collaborative intelligence: Theory and applications (**Yang**), Sensors and Biosensors Research (**Kiely**); International Journal of Theoretical and Applied Multiscale Mechanics (**Yao**), Journal of Power Sources (**Ieropoulos**), Metals Journal (**Bolouri**).

Member of editorial board: Swarm Intelligence (**Winfield A**), Journal of Experimental and Theoretical Artificial Intelligence (**Winfield A**), International Journal of Advanced Robotic Systems (**Smith M**), Machines: Machinery and Automation, (**Smith M**), Computers in Industry (**Smith M**), Sensors (**Smith M**), Journal of Production and Systems Engineering Management (**Smith M**), Theoretical and Applied Computer Science (**Zhu**), Sustainable Energy Technologies and Assessments (**Winfield J**), Complexity (**Zhu**), Control and engineering (**Zhu**), Control Science and Engineering (**Zhu**), Energy Reports (**Ieropoulos**), Advanced Manufacturing: Polymer & Composite Science (**Attwood**), Advanced Manufacturing: Polymer & Composite Science (**Cox**).

Conferences/Symposia: Staff have been involved in committees for numerous conferences and symposia, e.g. IEEE/ACM HRI, Robotics, Science and System, IEEE IROS, IJCAI, HAI, TAROS, European Fuel Cell Forum (EFCF), European Institute for Computational Neuroscience, International Conference on Bio-Sensing Technology (**Attwood, Cox, Giuliani, Kiely, Studley, Zhu**); Keynote address, Bill & Melinda Gates Foundation, 5-year Transformative Technology Review, and Plenary/Invited Talks for the Electrochemical Society, European Fuel Cell (Piero Lunghi) Conference, Biofilms (**Ieropoulos**).

Awards: Kelvin Medal, Glasgow Philosophical Society (**Winfield A**); Royal Academy of Engineering Enterprise Fellowship (**Kiely**).

Visiting Positions: Visiting Professor, University of York (**Winfield A**); Visiting Professor, North University of China (**Zhu**); Visiting Professor, Nanchang Hangkong University China (**Yao**), Visiting Fellow, University of Bristol (**Kiely**), Visiting Fellow, University of Manchester (**Smith M**), Visiting Researcher, Qiqihar University China (**Atkinson**), Visiting Senior Research Fellow, University of Bristol (**Pipe**).